

ENERGY HARVESTING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/447,317; U.S. Provisional Application No. 61/447,315; U.S. Provisional Application No. 61/447,328; U.S. Provisional Application No. 61/447,321; U.S. Provisional Application No. 61/447,307; and U.S. Provisional Application No. 61/447,324; all filed Feb. 28, 2011. All of which are hereby incorporated by reference in their entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with U.S. Government support under an Agreement/Project number: ARPA-E Contract number DE-AR0000040. The U.S. Government may have certain rights in this invention.

TECHNICAL FIELD

[0003] The present invention generally relates to energy harvesting systems, and more specifically, to shape-memory alloy heat engines.

BACKGROUND

[0004] Thermal energy is produced by many industrial, assembly, and manufacturing processes. Automobiles, small equipment, and heavy equipment also produce thermal energy. Some of this thermal energy is waste heat, which is heat produced by machines, electrical equipment, and industrial processes for which no useful application is found or planned, and is generally a waste by-product. Waste heat may originate from machines, such as electrical generators, or from industrial processes, such as steel, glass, or chemical production. The burning of transport fuels also contributes to waste heat.

SUMMARY

[0005] An energy harvesting system includes a heat engine, a driven component, and a coupling device configured to selectively couple the driven component with the heat engine. The heat engine may likewise include a first rotatable pulley, a second rotatable pulley spaced from the first rotatable pulley, and a shape memory alloy (SMA) material disposed about a portion the first rotatable pulley at a first radial distance and about a portion of the second rotatable pulley at a second radial distance. The first and second radial distances may define an SMA pulley ratio. Additionally, a timing cable may be disposed about a portion of the first rotatable pulley at a third radial distance and about a portion of the second rotatable pulley at a fourth radial distance, where the third and fourth radial distances may define a timing pulley ratio that is different than the SMA pulley ratio.

[0006] The SMA material may be in thermal communication with a hot region at a first temperature and with a cold region at a second temperature lower than the first temperature. The SMA material may be configured to selectively change crystallographic phase between martensite to austenite and thereby one of contract and expand in response to exposure to the first temperature and also to one of expand and contract in response to exposure to the second temperature,

thereby converting a thermal energy gradient between the hot region and the cold region into mechanical energy.

[0007] In one configuration, the driven component may be an electrical generator configured to convert rotational mechanical energy into electrical energy. In another configuration, the driven component may include at least one of a generator, a fan, a clutch, a blower, a pump, and a compressor. The driven component may similarly include a fly wheel. Additionally, the coupling device may include a selectively actuatable clutch and/or an adaptive torque transmitting device having a variable gear ratio.

[0008] A controller may be in communication with the coupling device and configured to control the selective coupling of the driven component with the heat engine. In one configuration, the controller may be configured to monitor a rotational speed of one of the first rotational pulley and second rotational pulley, and may decouple the driven component from the heat engine if the monitored rotational speed is below a predetermined threshold. In another configuration, the controller may be configured to monitor a temperature of the SMA material, and modify the gear ratio of the adaptive torque transmitting device to reduce a torque load on the heat engine if the temperature of the SMA material exceeds a predetermined threshold.

[0009] The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic diagram of an energy harvesting system including a heat engine;

[0011] FIG. 2 is a schematic side view of the heat engine of FIG. 1;

[0012] FIG. 3 is a schematic side view of another heat engine usable with the energy harvesting system of FIG. 1;

[0013] FIG. 4 is a schematic graphical representation of a work diagram for a heat engine, such as those shown in either FIG. 2 or FIG. 3;

[0014] FIG. 5 is a schematic side view of the heat engine of FIG. 1, configured with a spring-biased tensioning pulley;

[0015] FIG. 6 is a schematic side view of the heat engine of FIG. 1, configured to receive thermal energy from a source and produce a mechanical output;

DETAILED DESCRIPTION

[0016] Referring to the drawings, wherein like reference numbers correspond to like or similar components whenever possible throughout the several figures, there is shown in FIG. 1 an energy harvesting system 10. Features and components shown and described in other figures may be incorporated and used with those shown in FIG. 1. The energy harvesting system 10 shown includes a heat engine 14, a driven component 16, and a coupling device 17 configured to selectively couple the driven component 16 with the heat engine 14.

[0017] The energy harvesting system 10 utilizes a first fluid region or a hot region 18, having a first temperature. The hot region 18 may be in heat transfer communication with a heat source, such as waste heat, or may represent any region of relatively warm temperature to contribute to operation of the heat engine 14, as described herein. The energy harvesting system 10 also utilizes a second fluid region or a cold region